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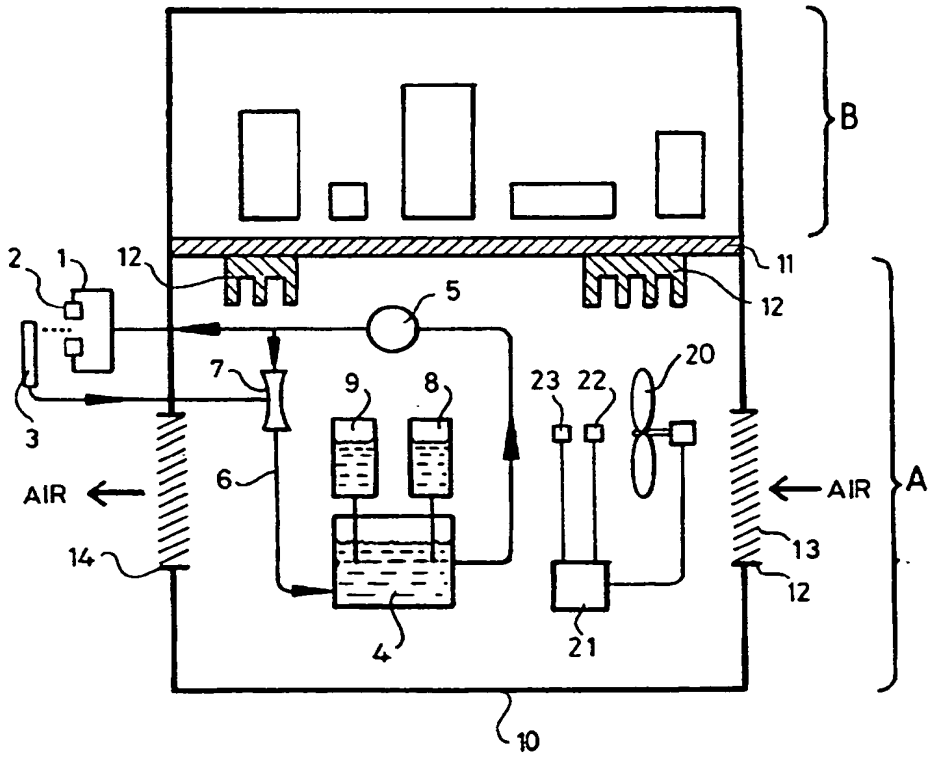
(54) Title: AIR FLOW DETECTION SYSTEM FOR A CONTINUOUS INK JET PRINTER

(57) Abstract

The present invention relates to an ink jet printer in which the ink flow system of the printer is housed in a housing (10A) and solvent vapours released from the system (4-9) into the housing are dissipated from the interior of the housing by an air stream driven by one or more fan means (20), characterised in that the flow of the airstream is monitored by means of one or more detectors (22, 23) which operate by monitoring a change in a variable affected by the air stream as against a reference value for that variable, which detectors (22, 23) are selected from a thermal flux flow detector assembly or a diaphragm actuated pressure differential detection mechanism. The invention also provides a method for operating a printer of the invention.



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AIR FLOW DETECTION SYSTEM FOR A CONTINUOUS INK JET PRINTER

The present invention relates to a device, notably to one for sensing the malfunction of a ventilating fan in a housing of an ink jet printer.

BACKGROUND TO THE INVENTION:

In many forms of ink jet printer, a solvent based ink is drawn from a reservoir and pumped to a print head for deposition through one or more nozzles onto a substrate. During the handling and use of the ink, solvent vapours escape and present a fire and safety hazard unless dispersed. In some forms of printer, the ink is recycled from the print head and the gutter used to catch unprinted droplets to the ink reservoir and the problems due to escape of solvent vapours are magnified.

It is usual to house the ink flow system of an ink jet printer in a housing and in some forms of printer the housing has solid walls which act to contain the solvent vapours and thus increase the local concentration of vapour to an unacceptable level. It has been proposed to dissipate the vapours by means of a fan which ejects the vapours from the housing in a carrier air stream, thus minimising local build up of vapours and diluting the vapours with the air stream generated by the fan.

However, if the fan malfunctions, for example stops, or the air flow from the fan is reduced, for example if the air filter through which the fan draws its supply of air becomes clogged, problems arise and may not readily be detected until safety limits have been exceeded. It is known to use a range of types of fan failure detector in situations where large volumes of air are being handled or the air velocity

from the fan is high. However, in an ink jet printer the volumes, pressures and flow rates are too low for many types of flow failure detector to be applicable. It has therefore been accepted by many in the ink jet printer field that it is necessary to provide large air ports in any printer casing to achieve natural air flow to dissipate the solvent vapours if one is to be certain of reducing concentrations of solvent vapour to acceptable levels. Such large ports are undesirable since they permit unauthorised access to the interior of the printer and allow the ingress of dirt, dust and moisture from the working environment which may affect proper operation of the printer and can lead to contamination of the ink in the ink flow system causing blockage or variable performance of the printer nozzles.

We have now found that certain types of detector can be used in the low volume/flow rate conditions obtaining in an ink jet printer housing and that such detectors provide a simple and effective means by which fan failure or air flow variation can be detected and a suitable alarm given before safety limits have been exceeded. As a result, it is possible to utilise substantially closed housings for ink jet printers, with the attendant reduction in damage to the electronic or mechanical components of the printer or of contamination of the ink due to external factors. It also makes it possible to utilise housings in which the electronic components of the printer are separated from the ink system by a physical barrier, which protects the electronic components from the corrosive effects of the solvents vapours. Hitherto, the use of such sub-divided housings carried the risk that unacceptable concentrations of solvent vapour would rapidly build up due to the smaller effective housing volume occupied by the components of the ink flow system of the printer.

SUMMARY OF THE INVENTION:

Accordingly, the present invention provides an ink jet printer in which the ink flow system of the printer is housed in a housing and solvent vapours released from the system into the housing are dissipated from the interior of the housing by an air stream driven by one or more fan means, characterised in that the flow of the airstream is monitored by means of one or more detectors which operate by monitoring a change in a variable affected by the air stream as against a reference value for that variable, which detectors are selected from a thermal flux flow detector assembly or a diaphragm actuated pressure differential detection mechanism.

Preferably, there is provided means which actuates an alarm and/or disables operation of the printer if the variable being monitored deviates from a predetermined value.

The invention also provides a method for operating an ink jet printer comprising a housing containing the ink flow system for the printer, characterised in that an air stream is caused to flow over the ink flow system by means of one or more fan means and the operation of the fan means is monitored by means of one or more detectors which operate by monitoring a change in a variable affected by the air stream as against a reference value for that variable, which detectors are selected from a thermal flux flow detector assembly or a diaphragm actuated pressure differential detection mechanism; and actuating an alarm means and/or disabling the printer operation if the change in the variable being monitored deviates from a predetermined value.

The term fan means is used herein to denote in general any

means by which a flow of air can be generated and includes axial and radial flow fans, propeller type fans, turbine impeller type fans, piston and other positive displacement pumps. For convenience, the invention will be described hereinafter in terms of a simple axial flow fan driven by an electric motor. Many such fans are commercially available and may be used with little or no modification in the present invention.

The invention can be applied to any form of ink jet printer, notably to continuous ink jet printers in which at least part of the ink fed to the print head is recycled for re-use. Furthermore, the invention is of especial application in those forms of ink jet printer in which the ink flow system is housed within a closed housing and is separated from the electronic components of the printer by a partition wall within the housing. For convenience, the invention will be described in terms of an ink jet printer housed within such a sub-divided substantially closed housing.

In such a housing, air is drawn into the housing through a inlet by one or more fans. Preferably, the air passes through one or more filter elements, for example a filter pad or the like, to remove extraneous particles in the air stream. The filter elements can incorporate chemical or other scrubbing means to remove chemical constituents from the airstream if desired. Such filter elements are available commercially and may be used in their commercially available forms.

The air stream from the fan(s) flows across the ink reservoir and any make up ink and solvent reservoir bottles or other containers and the lines of the ink flow and/or recovery systems. For convenience, the term ink flow system is used herein to denote all parts of the ink storage,

pressurisation, delivery or recovery systems of the ink jet printer. The print head containing the nozzle outlets through which the ink is ejected from the print head to form the droplets which are to be printed usually lies outside the housing, for example as a separate component connected to the ink system by an umbilical cord containing ink and electrical control lines; or as a nozzle plate mounted on or as a part of an external wall of the housing. The print head thus will not usually form part of the ink flow system over which the air stream from the fan flows.

The air stream entrains such solvent vapours as may be released from the ink flow system and carries them in diluted state out of the housing for further dissipation in the atmosphere around the printer. Typically, the solvent vapour laden air stream vents through one or more outlets in a suitable external wall of the housing, notably one removed from that through which the air enters the housing, so that the air stream flows over as much of the ink flow system as possible and discharges at a point removed from the air intake. Alternatively, the solvent laden air stream can be discharged through the open base of the housing.

As indicated above, the housing for the ink flow system is a substantially closed housing, that is apart from the air inlet and outlet ports, the housing contains the solvent vapours and air stream and does not dissipate them into the atmosphere through other openings in the housing wall. The use of such a substantially closed housing and fan assisted ventilation of the housing may make it feasible to vent the solvent laden air stream to a common disposal line serving a number of printers and from which it may be feasible to recover solvent values, for example by cooling the air stream in the common disposal line to condense out at least part of the solvent values for re-cycle to one or more of

the printers. Alternatively, the solvent outlet can be provided with cooling means to recover at least part of the solvent values from the solvent laden air stream at the individual printers.

Typically, such substantially closed housing systems operate at a positive pressure of no more than about 0.1 bar and an air flow rate of no more than about 20 litres per minute per square centimetre. Such low pressures and flow rates cannot readily be monitored effectively by many types of detectors which are economically viable for use in ink jet printers. Surprisingly, we have found that two types of flow or pressure detector specified herein are suitable for use under such conditions and provide a number of benefits.

As stated above, the detector systems for present use operate on the principle of monitoring a variable which is affected by the existence of the air flow against a reference value of that variable so as to detect variations in the differential between the reference and monitored variable, as opposed to attempting to detect absolute values for the variable as many flow detection systems do. In this way, minor variations in the monitored variable can be detected and any changes in ambient conditions, for example operating temperature, are largely compensated for by the change in the reference value for that variable which occurs at the reference detector, thus reducing the problems of temperature variation from which many flow detectors suffer.

One type of detector for present use is a thermal flux flow sensor system which measures the change in resistance of a heated sensor placed in the air stream. A single such detector can be used, and the signal from that sensor compared with a reference value for the predicted signal which would be obtained if the air flow system is operating

correctly. However, it is preferred to provide a second detector, also located in that air stream, which provides a calibration signal reflecting the ambient conditions in the housing so that fluctuations in temperature within the housing can be compensated for by subtracting the calibration signal from the signal from the first detector. For convenience, the invention will be described hereinafter in terms of the use of two thermal flux flow detectors.

Thus, from a preferred aspect the invention provides a printer or method of the invention in which the detector comprises two thermistor devices located in the air stream generated by the fan means, one thermistor being connected to a source of electrical power so as to heat the thermistor and provide an output signal current related to the air flow over the thermistor and the other thermistor not being adapted to be heated and providing an ambient temperature variation compensation signal.

Preferably, the thermal flux flow detector system comprises a first and second thermistor located adjacent one another in the flow of the air stream. The first thermistor monitors the ambient temperature of the air flow; and the second thermistor is connected to an electric current so that this second thermistor can be heated. Typically, each thermistor comprises a thick film ceramic containing a thin film resistance temperature detector, the second having one or more thick film heater resistors to heat the thermistor, the first thermistor not having the heater resistors. Such thermistors are commercially available. Application of a voltage to the resistors causes them to heat up and radiate heat to the detector. The air flow over the thermistor reduces the thermal flux perceived by the detector which affects the resistance of the detector. This variation in the resistance can be detected by applying a constant current to the second thermistor and monitoring the change

in voltage across the detector. In the case of the first thermistor, the voltage is not applied to the resistors and the detector responds solely to the ambient temperature of the air flow. By monitoring the variation in the voltage signals from the heated thermistor, any change in the air flow from the fan can be detected. This change can then be used to actuate an audible and/or visual alarm and/or to disable operation of the printer, for example by switching off the ink flow pump when the flow rate falls below a preset level, say 0.05 bar. By subtracting the voltage signal from the first, unheated, thermistor any variation in the voltage of the second thermistor due to variation in ambient temperature can be largely compensated for.

Such a system can utilise conventional circuitry and components and the optimum selection of components and operating conditions can be achieved using simple trial and error. By using the unheated thermistor, not only is a reference signal generated against which variations in the signal from the heated thermistor can be monitored, thus compensation for differences in the performance of different batches of thermistors from a manufacturer, but the reference signal will also vary with a change in ambient temperature and thus provide an automatic compensation for the effect this temperature variation will have on the signal from the heated thermistor. It is therefore preferred to use thermistors which have substantially the same temperature characteristics for the heated and reference thermistors to enhance the temperature compensation effect of the reference thermistor.

In the other detector system for use in the invention, a diaphragm is located with one side exposed to the slight positive pressure within the housing and the other side is exposed to a fixed, lower pressure which acts as the

reference pressure, for example in a sealed vacuum unit. The diaphragm carries an electrical contact on its low pressure side which contacts another contact within the low pressure sealed unit when the diaphragm flexes due to a given pressure differential across the diaphragm. One such detector can be used to detect the existence of the required minimum positive pressure in the housing when the air flow is operating properly, in which case the contact between the diaphragm and the sealed unit contact is broken when the pressure falls below that level. If desired, a second such detector operating at a different pressure differential can be used to detect when the pressure within the housing rises above a given level, for example due to blockage of the outlet port filter or due to obstruction of the air flow out of the outlet port, for example when the printer is located too close to a wall or other structure. In this case the electrical contact of the detector is made when the upper pressure limit is exceeded.

The flow/pressure detectors may be used in combination to detect a number of different malfunction conditions and to actuate any suitable audible and/or visual alarm system to alert an operator of the malfunction. However, it will usually be preferred that the actuation of the detector should also disable the operation of the printer so that the risk of excessive solvent vapour build up within the casing can be reduced. For example, the power supply to the pump feeding ink to the print head can be switched off when the detector is actuated using a conventional control and relay circuit.

As stated above, it is surprising that the detectors for present use should be capable of use in the very low pressure and/or flow rate conditions obtaining in an ink jet printer housing. The use of such detectors enables an

operator to monitor the operation of the solvent vapour dissipation mechanism without the need for repeated inspection and readily lends itself to automatic operation and recording of pressure/flow fluctuations observed by the sensors. Furthermore, the use of such detectors enables an operator to meet current stringent health and safety requirements for solvent vapour concentrations with minimal modification of existing ink jet printer equipment using cheap and commercially available components whose signal output can readily be monitored by simple electronic control circuits. Thus, the output from both types of detector for present use are electrical signals which can be used directly, as in the case of the pressure diaphragm switch, to actuate the alarm or disable the printer. Where the reference value for the variable is expressed as a signal output, as with two thermistors, the reference and observed signals are fed to a conventional comparison circuit, for example a differential amplifier, to detect the variation between the observed and reference values for the variable being monitored. The output from this comparison can be a simple yes/no type of signal, but will usually be a second quantitative signal expressing the difference between the reference and observed signals and this difference is than compared with the permitted range for that difference, for example using a simple comparison between the monitored difference value and the value in a memory which corresponds to the permitted flow rate fluctuation which has been determined during normal operation of the air flow system. If the monitored difference deviates excessively from the permitted value, then the comparison circuit generates a signal to actuate the alarm or disable the printer. Such comparison, memory and control circuits can be of conventional design and construction.

DESCRIPTION OF THE DRAWINGS:

A preferred embodiment of the invention will now be described by way of illustration with respect to the accompanying drawings in which Figure 1 is a diagrammatic vertical section through an ink jet printer housing incorporating a fan failure device of the invention; and Figure 2 is a schematic block diagram for the circuit used in the device of Figure 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT:

A continuous jet printer comprises a print head 1 having an ink flow system A to feed ink to the nozzle 2 and to recycle droplets issuing from the nozzle which are not to be printed and are caught in the gutter 3. The flow system incorporates an ink reservoir 4, an ink circulation pump 5, a return ink bypass line 6, a venturi pump 7 in the line 6 and driven by ink flowing through the line 6 which is not fed to the nozzle 2. The gutter 3 is connected to the throat of the venturi pump 7 so that a vacuum is drawn on the gutter 3 to draw ink from the gutter into the venturi 7 and, hence, back to the reservoir 4. Make up solvent and ink bottles 8 and 9 are connected to the reservoir 4 or to any other suitable point in the ink flow system to top up the ink level in the flow system as ink is lost during print-ing and to add make up solvent to replace solvent which is lost from the ink due to evaporation so as to keep the viscosity of the ink within desired limits using conventional viscosity monitoring control systems (not shown).

The ink flow system A is mounted within the basal portion of a substantially closed housing 10. Within the upper portion of the housing 10 is located the electronic circuits B (shown schematically as blocks) for controlling the

operation of the printer. The circuits B are separated from the ink flow system A by a horizontal partition 11, which can carry finned heat sinks 12 or the like on its lower face to dissipate heat from the circuits B into the air stream flowing through the basal portion of the housing.

The housing 10 is provided with an air inlet port 12 in a side wall thereof. The port 12 can be provided with a filter mesh or other filter medium 13 to inhibit the ingress of dust, fibres and other contaminants into the housing 10. The housing is also provided with an air outlet port 14 located at some point removed from the inlet 12 so that air flows through the housing 10 and over the ink flow system. The port 14 may be provided with a filter medium if desired. The air is caused to flow over the ink flow system by means of one or more fans 20 which are located adjacent to the air inlet 12 and whose operation is controlled by a conventional control circuit 21. Located in the air stream downstream of the fan 20 is a first thermistor thermal flux flow device 22. A second thermal flux flow device 23 having substantially the same temperature characteristics as device 22 is mounted adjacent device 22 so that it is in the same air flow as device 22. The devices 22 and 23 are connected to the control circuit 21, which incorporates means for detecting the voltage signal outputs from the two devices and for comparing them to detect variations in the difference between the signals. Such means can be of conventional design and construction. The device 22 is typically a thermistor device comprising a thin film sensor located between two heat emitting resistors, the whole being incorporated in a thick film ceramic carrier. The device 23 is similar to device 22, but does not incorporate the heater resistors.

In operation, ink flows through the ink flow system and

solvent vapours are generated which would otherwise accumulate within the housing 10 and present an unacceptable fire and health hazard. The fan 20 is operated to draw air into the housing through inlet 12, to pass the air over the ink flow system to entrain the solvent vapours and to discharge the solvent laden air stream through outlet 14 where it diluted by the external ambient air to reduce the solvent vapour concentration to acceptable levels. Typically, the fan produces a positive air pressure within the housing of from 0.05 to 0.25 bar, notably about 0.075 to 0.15 bar, and a flow rate of from 5 to 20, preferably from 7.5 to 12.5, litres per minute per square centimetre. If desired, the air outlet can incorporate, or discharge the solvent laden air stream to, a cooling device to cool the air stream to below its dew point so as to condense out at least part of the solvent values from the air stream prior to discharge to the atmosphere.

A voltage, preferably a low voltage to reduce fire hazards, for example 5 to 24 volts, is applied to the resistor elements in device 22 so that the device is heated, for example to from 60 to 120°C and causes a thermal flux to flow towards the detector within the device. The flow of air over device 22 affects the thermal flux perceived by the detector and hence its resistance. By applying a constant current to the detector, the variation in resistance gives a variation in the voltage across the detector and this is monitored by control circuit 21. The device 23 is run cold so that it monitors the ambient temperature within the housing and thus acts as a reference for the temperature detected by device 22 and compensates for variations in the ambient temperature.

When the air flow over device 22 changes, for example due to the failure of the fan 20 or due to blockage of the air

outlet 14, the voltage output from device 22 changes and the difference between the voltages from the devices 22 and 23 will change. This is detected by circuit 21 and if the difference falls outside a predetermined range, circuit 21 actuates a visible alarm and also switches off pump 5 so as to disable operation of the printer.

The devices 22 and 23 and circuit 21 can take a number of forms. However, a preferred form of the devices and circuit 21 is shown in Figure 2. As indicated above, the device 22 preferably comprise a thin film resistance temperature detector 40 having thick film heater resistors 41, 42 located to each side of the detector 40, the whole being encased in a thick film ceramic. Device 23 is simlar to device 22, except tht it does not incorporate the resistors 41, 42. Regulator U10 ensures that a constant +5v DC is applied across the resistors 41, 42 in device 22. Transistors Q49 and Q50 ensure that a constant current of about 1mA is applied to the detectors 40 in the devices 22 and 23. The voltages across the detectors are combined to give a differential using differential amplifier U8 and this differential is amplified by a factor of 10. This amplified differential is then compared with a reference voltage value corresponding to the minimum airflow required for satisfactory operation of the printer. If the differential output exceeds the permitted variation about the reference voltage, the control circuit will actuate an alarm and will switch off pump 5.

The components and their values used in this circuit are of conventional design and construction and the optimum values for the components can be selected according to known principles according to the specific requirements of each printer design.

CLAIMS:

1. An ink jet printer in which the ink flow system of the printer is housed in a housing and solvent vapours released from the system into the housing are dissipated from the interior of the housing by an air stream driven by one or more fan means, characterised in that the flow of the airstream is monitored by means of one or more detectors which operate by monitoring a change in a variable affected by the air stream as against a reference value for that variable, which detectors are selected from a thermal flux flow detector assembly or a diaphragm actuated pressure differential detection mechanism.

2. A method for operating an ink jet printer comprising a housing containing the ink flow system for the printer, characterised in that an air stream is caused to flow over the ink flow system by means of one or more fan means and the operation of the fan means is monitored by means of one or more detectors which operate by monitoring a change in a variable affected by the air stream as against a reference value for that variable, which detectors are selected from a thermal flux flow detector assembly or a diaphragm actuated pressure differential detection mechanism; and actuating an alarm means and/or disabling the printer operation if the change in the variable being monitored deviates from a predetermined value.

3. A printer or method as claimed in either of claims 1 or 2, characterised in that the detector is a thermal flux flow detector device.

4. A printer or method as claimed in claim 3, characterised in that the thermal flux flow detector device is a thermistor device.

5. A printer or method as claimed in any one of the preceding claims, characterised in that detector comprises two thermistor devices located in the air stream generated by the fan means, one thermistor being connected to a source of electrical power so as to heat the thermistor and provide an output signal current related to the air flow over the thermistor and the other thermistor not being adapted to be heated and providing an ambient temperature variation compensation signal.

6. A printer or method as claimed in either of claims 4 or 5, characterised in that the thermistor device comprises a thick film ceramic containing a thin film resistance temperature detector in combination with one or more thick film heater resistors.

7. A printer or method as claimed in either of claims 1 or 2, characterised in that the diaphragm actuated pressure differential detector comprises a diaphragm located with one side exposed to the slight positive pressure within the housing and the other side is exposed to a fixed, lower pressure which acts as the reference pressure, the diaphragm carrying an electrical contact on its low pressure side which contacts another contact within the low pressure zone when the diaphragm flexes due to a given pressure differential across the diaphragm.

8. A printer or method as claimed in any one of claims 1, 2 or 7, characterised in that a second pressure detector is used to monitor excessive pressure rises within the housing.

9. A printer or method as claimed in any one of the preceding claims, characterised in that the air flow through the housing is less than 20 litres per minute per suare centimetre and the housing operates at a positive pressure

of up to 0.25 bar.

10. A printer or method according to any one of the preceding claims substantially as hereinbefore described with respect to the accompanying drawings.

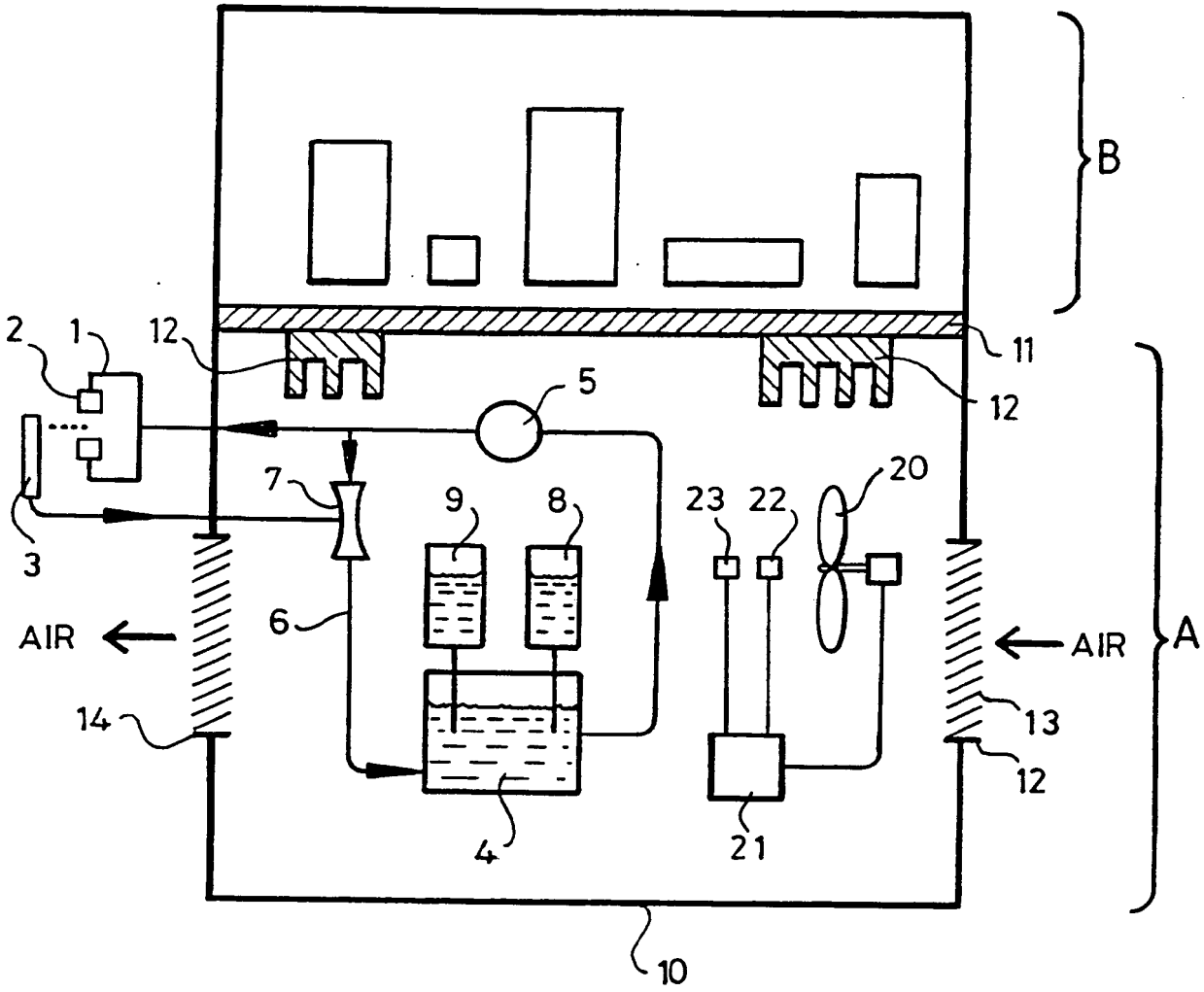

Fig. 1

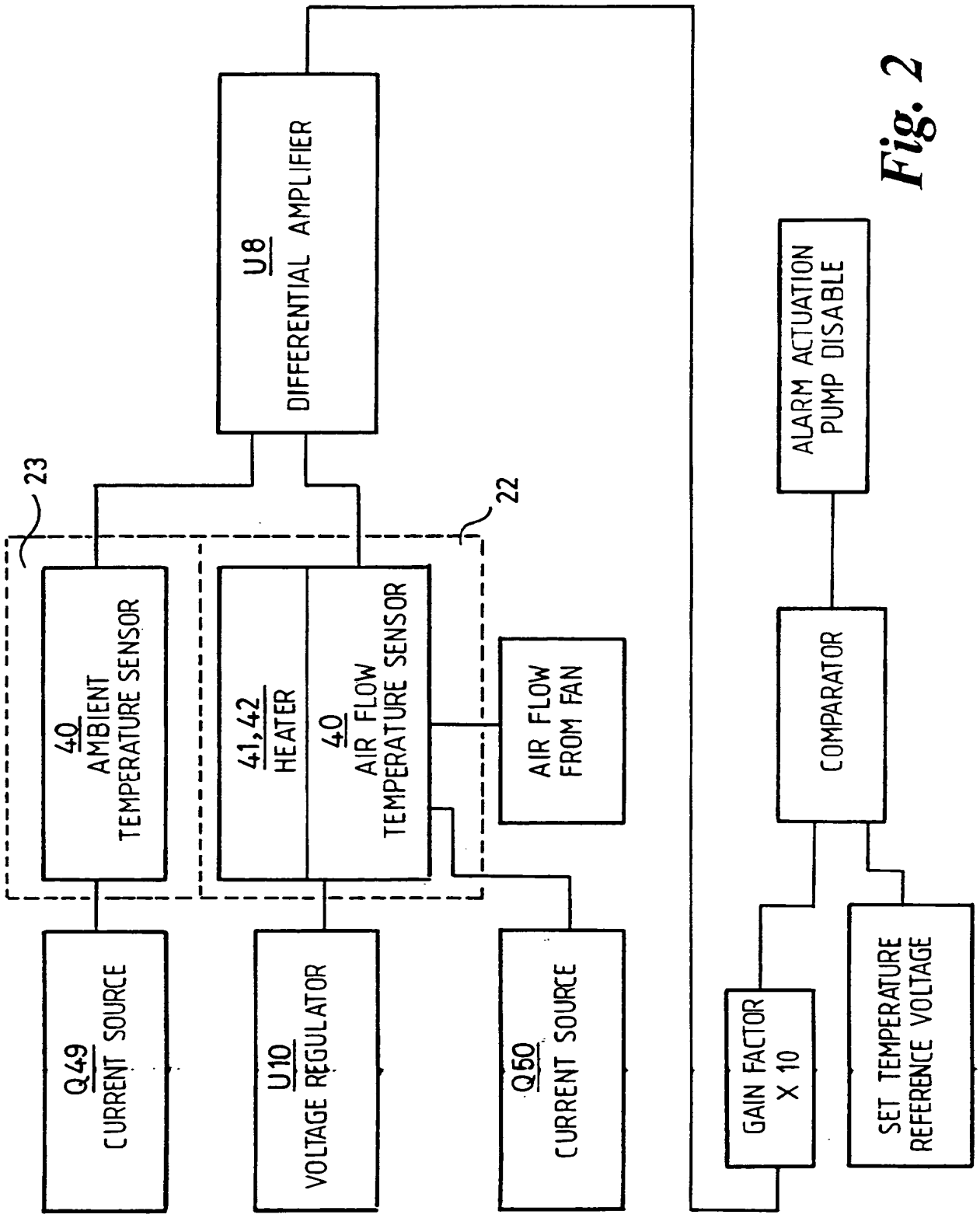

Fig. 2

INTERNATIONAL SEARCH REPORT

Int .onal Application No
PCT/GB 94/00329

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 B41J29/377

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 B41J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A,4 704 620 (ICHIHASHI ET AL.) 3 November 1987 see abstract; figures	1,2,10
A	PATENT ABSTRACTS OF JAPAN vol. 5, no. 25 (M-55) (697) 14 February 1981 & JP,A,55 152 065 (RICOH K.K.) 27 November 1980 see abstract	1,2,10
A	EP,A,0 040 556 (THE BENDIX CORPORATION) 25 November 1981 see page 9; figures 1-4	1,2

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☒ Patent family members are listed in annex.

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Date of the actual completion of the international search
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Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Int .onal Application No
PCT/GB 94/00329

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
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